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Automatic Vehicle Detection and Recognition

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By

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ABSTRACT

Security is extremely concerning point in distinctive applications, and in vehicle identification it is obligatory to raise alert on any suspicious activity. Such models can be utilized as a part of Border Security, Bank Security etc. In order to detect any vehicle we need to extract its features. Machine vision can be used to extract these features. Furthermore, vehicles have some of the features that may not be unique e.g. color, shape etc. Nevertheless, license plate is a unique identity of a vehicle which can identify its owner. Conversely, it can be tampered with and can be transferred to different vehicle easily. Hence we propose a new model which will combine automated license plate detection along with shape of the vehicle for e.g. SUV, Sedan and Hatchback. Finally, we compare our results with the database which has the legitimate features and information of that vehicle and which will automatically, raise an alert if any discrepancy is found.

Keywords: Licence Plate Detection and Recognition, Pre-processing, Number plate localization, Character segmentation, Character recognition, Vehicle Shape Detection and Recognition.

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LIST OF ABBREVIATIONS/SYMBOLS

AVDR – Automatic Vehicle Detection and Recognition

ALPDR – Automated Licence Plate Detections and Recognition

VLPDR - Vehicle Licence Plate Detections and Recognition

VSDR – Vehicle Shape Detection and Recognition

RADAR - Radio Detection and Ranging

LASER - Light Amplification by Stimulated Emission of Radiation

RFID – Radio Frequency Identification

OCR - Optical Character Recognition

IWT -Inverse Wavelet Transform

PD - Partial Discharges

SNR - Signal to Noise Ratio

MSE - Mean Squared Error

LTI - Linear Time Invariant

ROI - Region of Interest

DWT - Discrete Wavelet Transform

JPEG - Joint Photographic Experts Group

CHAPTER 1: INTRODUCTION

In the present period, the exponential rise of vehicular movement has turned into a huge reason of worry amongst the population staying in the capitals, metropolitans and urban areas. This subsequently has made it troublesome for different law implementation offices to monitor every one of the vehicles on streets. These agencies are responsible for nabbing the vehicles which are breaking many of the traffic rules. If we consider violations against security and how the culprits attempt to do their malign plans, we begin to acknowledge exactly how regularly a vehicle is part of it. Identification of the vehicle is also crucial for electronic toll machines. Thus, electronic toll accumulation depends profoundly on recognizable proof of the vehicle rapidly and precisely. Not just that, identification of vehicles play an important role in national security as well. In some countries, cross border security also requires the vehicle to be identified before they cross into another country.

In 2014 there were 907 million passenger vehicles and 329 million commercial vehicles registered worldwide, in comparison with 2006 stats which had 678 million passenger vehicles and 248 million commercial vehicles [42]. This shows an increase of 33.7% in passenger vehicle numbers and 32.6% in commercial vehicles. If this increase in trend keeps its pace, then till 2035 there will be approximately 1.7 billion register vehicles on road worldwide [41]. This brings up a need to implement a system which can identify the vehicles effectively and accurately. Some areas which can benefit from such a system is safety, traffic violations which in turn can help keep roads a safe place for public. VLPDR (Vehicle Licence Plate Detection and Recognition) System is a System that can extract information regarding vehicle by analyzing the images of the vehicle automatically and providing more detailed information about it.

To keep track of all the vehicles, law agencies worldwide implement licence plate techniques to give each vehicle its unique identification. Some history books say that in North America, New York was the first city to require that licence plates be appended to vehicles on April 25, 1901. Others assert West Virginia and Massachusetts ought to be given that respect, subsequent to their enactment was all inclusive and required the utilization of authoritatively delivered plates in 1903. In Canada, British Columbia began enlisting vehicles in 1903, yet it was up to the owner to make up markers to show the appointed enrollment number [37]. At present, all vehicles which are being used to transport people or goods across world are required by law to be registered with their respective state authorities. This registration helps in identification of the owner of the vehicle and the identity of the owner is linked to the vehicle plate.

Since we can see that the need of License Plate Detection and Recognition has not developed now but rather numerous years back, a few studies have been done in this field. So to better understand the previous studies it will be helpful to contemplate the set up frameworks under two classes; Active and Passive. The active ones use laser and radio frequency techniques to read the licence plate number of the vehicle. In this strategy, a scanner tag is put on the auto with the assistance of laser frameworks. These scanner tags makes it conceivable to introduce other data identified with the vehicle, alongside the licence plate. In the radio frequency technique, RFID reader is placed on the toll booth or traffic lights and can read the tag information of the vehicle from a distance. Hence, the vehicle is recognized. But the cost of these systems is very high and hence it is used where the risk of error is highly unacceptable.

Whereas the passive one majorly focuses on getting the picture of the Licence plate and then further process it to fetch the vehicle information. Since this system works completely around the image of the Licence plate, the recognition of it totally depends upon the image quality. Image noise such as intensity of light, shadows of objects apart from the vehicle etc. can always play a part in making the recognition of the plate difficult and hence, can lead to incorrect results.

But, these systems entirely depend on recognizing just one feature of the Vehicle and that is its Licence plate. The only unique feature of a Vehicle is its Licence Plate, but it can be easily tampered with. In 2012, more than 2000 Licence Plates were stolen off the cars in Edmonton and in the first six months of 2013, over 1,100 Licence Plates were reported stolen across the city of Edmonton. Calgary Police says that there is an increase of 80% of licence plate theft increase in 2015 as compared to 2014[34]. And these stolen plates can be used to perform various acts of malign nature and the owner can be falsely implicated for an act which he/she has not performed. This problem led to a system which recognizes the vehicle with not only just Licence plates but also tie another feature of the car with that recognition can help to eliminate such threats. In the approach taken in this thesis along with the Licence plate recognition, the shape of the vehicle is also taken into account. Such systems can be installed in facilities which rely on the correct authentication of the person to enter the premises.

In this thesis, a new technique is discussed which combine licence plate recognition system with the shape recognition to provide better credibility of the vehicle entering the facility.

1.1 Thesis Motivation

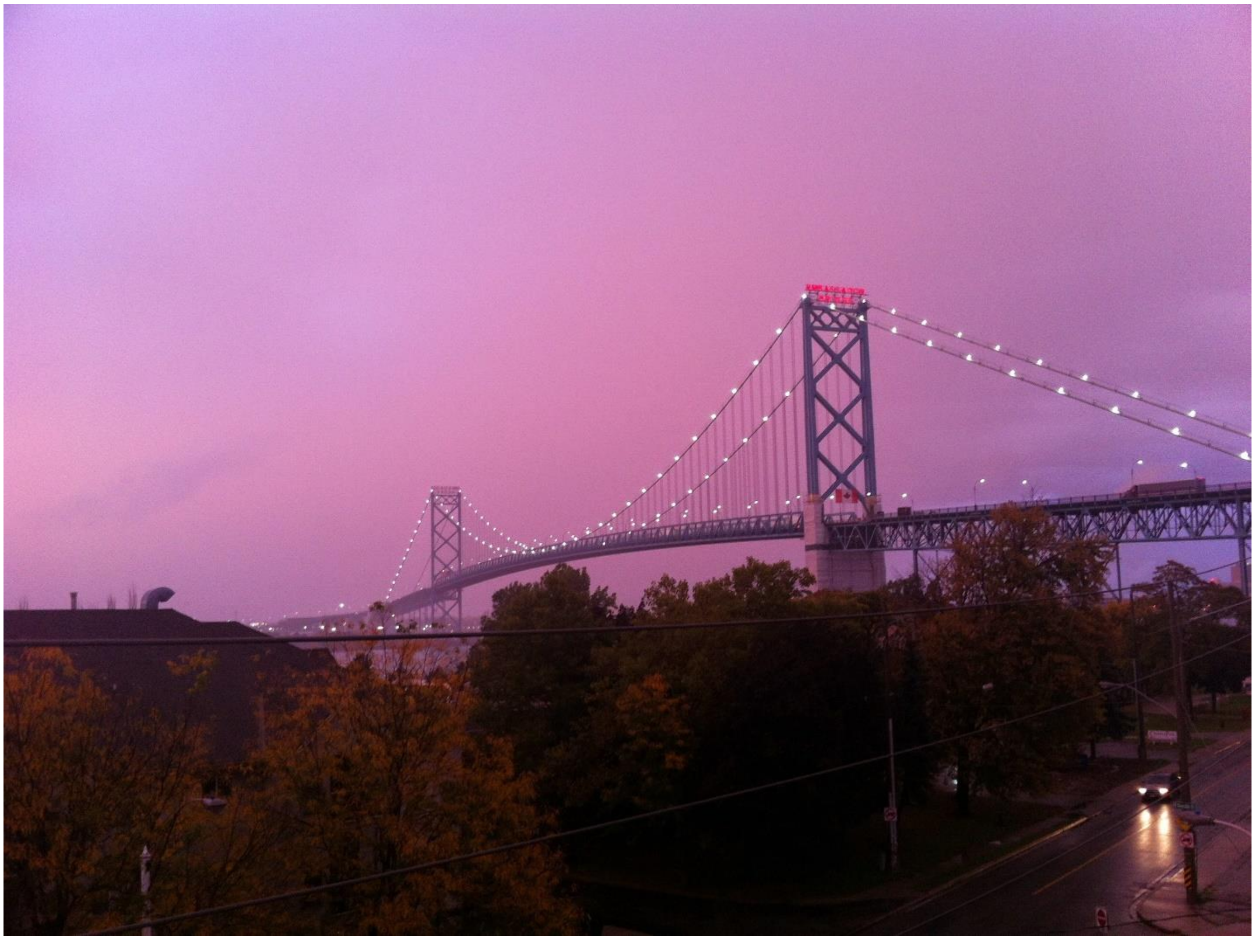

Figure 1 - Ambassador Bridge, Windsor, ON, Canada

At the border of US/Canada at the ambassador bridge they use cameras to automatically detect the Licence plates of vehicles right before it enters the booth for authentication to cross the border. The system in place at this particular border crossing uses, Automatic Licence Plate Detection System. ALPD systems could be coupled with the shape recognition. This can help in scenarios where if a person uses a Licence plate of a Sedan car on a S.U.V (Sports Utility Vehicle), then the System would raise a flag to the concerned authorities. This is just one of the applications of this system. Such a system can be of help in following areas as well:

1.1.1 Convenience

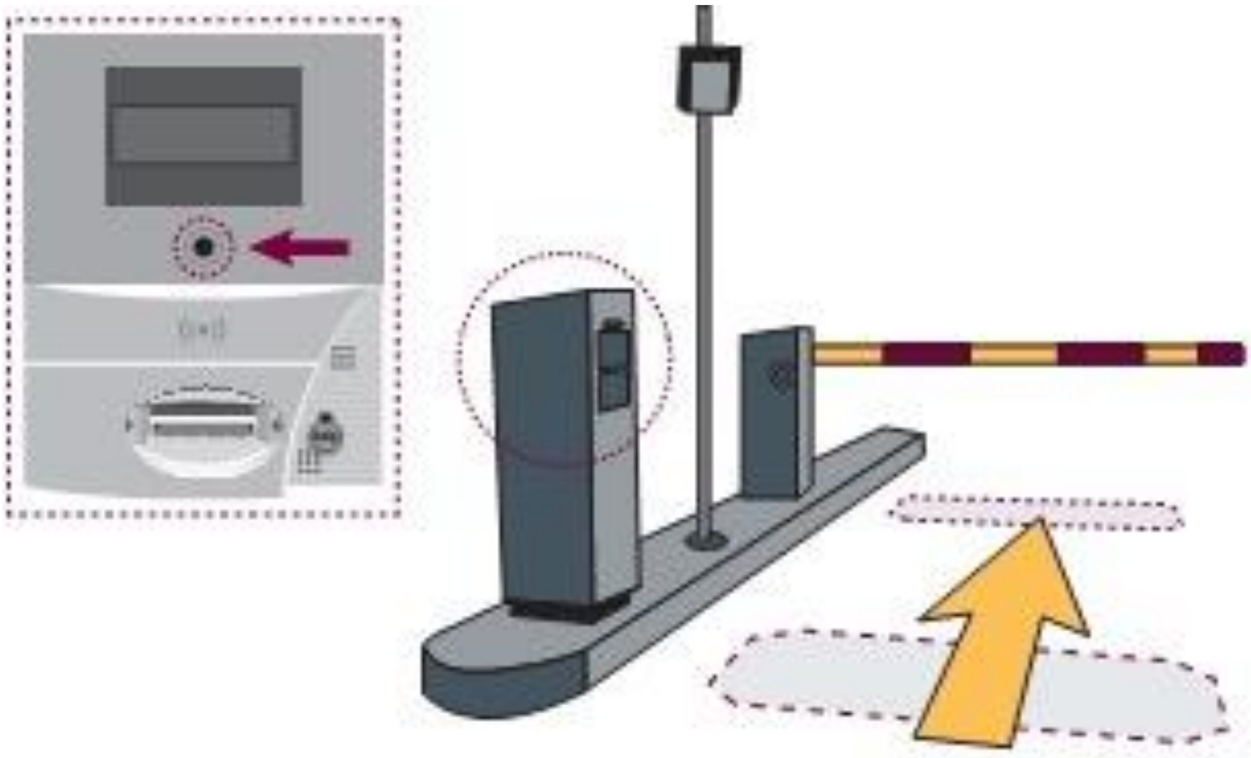

Figure 2- Parking Enforcing System Diagram

The system we see above in figure 2 is a common system which we see in our daily life. These systems are placed in various private parking facilities across the city. The basic principle of these systems is issuing a ticket for new vehicles which use the facility. For the vehicles which use that facility every day, the facility maintains a database and issues RFID tags to those vehicles. An RFID reader is placed at the toll booth which reads the RFID tags issued to these vehicles and let them enter the facility without any delay. Every time a vehicle which is not in the database uses these facilities, the owner has to get out of the car and lean towards these pillars which either issue the tickets. Now this process requires too much recourse in terms of paper used for tickets and hardware involved in making RFID tags. Also this task is strenuous for the user of the vehicle and it takes some time to complete all these steps.

If we replace this system with a couple of cameras and eliminate the need to issue RFID tags, this will reduce the user's effort to enter the facility which, he/she comes every day to perform certain daily tasks. This system can identify the car by recognising the Licence plate and also the shape of the vehicle. Then the system can match the vehicle's credentials in its database, if it finds a match then the vehicle is allowed to enter the facility. This enables the vehicles which have been registered with the facility to pass without any delay. This saves time of the user as well as save the resources.

1.1.2 Security

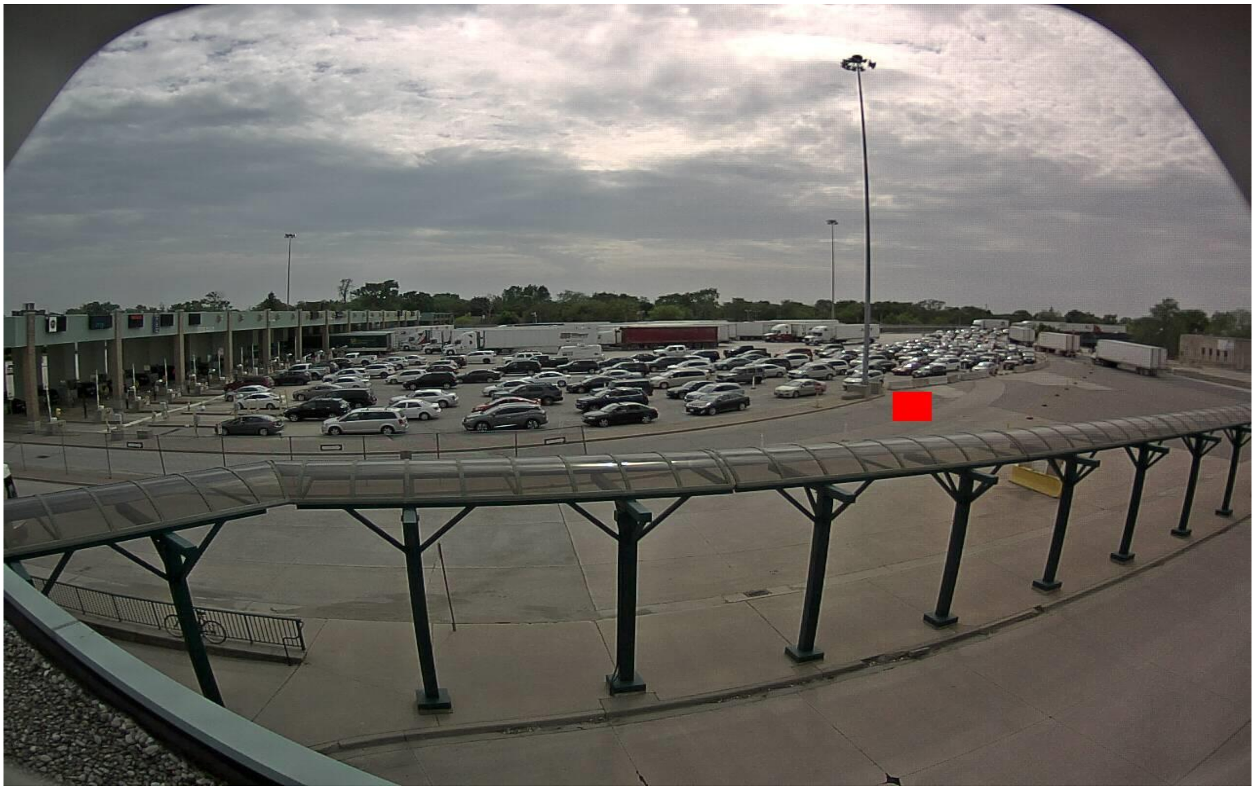

Figure 3 - Security Check Post – Canadian Plaza, (Travelling to Canada) [38]

The above figure illustrates the security check at Ambassador Bridge, Ontario, Canada. We see multiple lanes for entry to Canada, and each lane has one security post. In each security post one security officer checks the credentials of the vehicle and its driver before he/she is allowed to cross. These types of systems have two aspects working together. The first part of this application consists of an officer who is there to identify the vehicle and its passengers. The officer does this by cross checking the credentials of the vehicle with the database. This system consists of a camera which aids the officer by recognition of the license plate. After recognition of the license plate, the system notifies the security personnel if this vehicle is involved in any type of illegal activity. This lets the officer to examine the vehicle more precisely and makes this time consuming and labour intensive process easier. Examples of such facilities are Border Security Systems, Industrial estates, Financial Institutes etc.

1.1.3 Tracking of Vehicles

Figure 4 - Toll booth [44]

The above figure shows a toll booth in which the vehicle is required to stop before it can cross off and continue to its journey. These toll booths are time consuming and often cause congestion on the road for its travelers. This can be eliminated by the help of implementing the systems which read the Licence plate and sends the charge for using the toll road directly to the owner of the vehicle. This reduces the labor intensive work which involves stopping each vehicle and charging them before they use the toll road. Such system is in place on Highway 407, Ontario, Canada [43]. This system implementation is also cost effective as only cameras are required to install on the entry of the roads.

1.2 AVDR System

Detection of the vehicle has become a serious initiative and an advanced area of research, which is possible through the application of VLPDR (Vehicle Licence Plate Detection and Recognition). Hence, VLPDR Systems can be taken into account, which primarily works by capturing the vehicular images and thus, interprets the Licence plate's registration number automatically. AVDR (Automatic Vehicle Detection and Recognition) scheme proves to be an effective tool which helps to mechanize the hectic, tedious and the physical procedure of the workers which they encounter and deal with in their regular day life, and serves to provide efficiency in the identification of the vehicles from hundreds and thousands of vehicles observed in the regular patrolling task. AVDR combines Licence plate detection with the shape detection of the vehicle to make a system which is more susceptible to false intrusions.

AVDR system is divided into two separate modules:

1.2.1 ALPDR System

"Automated Licence plate detection and recognition (ALPDR) technology was first invented in the year 1976, by the Police Scientific Development Branch (PSDB), Home Office, United Kingdom" [4]. ALPDR system comprises of different components. The key module of this system is to recognize the text in an image. This image contains the licence plate of the vehicle which is then analyzed to get the plate information. Each character of the licence plate is recognized by this system by comparing with the stored templates. Licence plate number of any vehicle is related to many features in a vehicle database which helps to describe it. Some of the features are listed below:

1. Make and Model of Vehicle
2. Colour of Vehicle
3. Year of Manufacturing
4. Engine type and size
5. Fuel type used the vehicle
6. Mileage recorded by the vehicle
7. Vehicle Identification (Chassis) Number
8. The name and address of the owner of the vehicle

1.2.1.1 Types of ALPDR System

The need for the successful implementation of the Licence Plate Detection and Recognition (LPDR) system has evolved during many years and hence, many research algorithms, protocols and schemes have been proposed on the topic. Therefore, ALPDR (Automatic Licence Plate Detection and Recognition) System can be described under two main divisions [28]:

1. Online or Active ALPDR System
2. Offline or Passive ALPDR System

1.2.1.1.1 Online or Active ALPDR System

In an Active ALPDR System, technologies like LASER, RADAR, surveillance cameras and radio frequency are implemented in order to carry out a successful identification of the vehicle.

In LASER System, a barcode is positioned on the car whereas in the case of radio frequency systems, a tag is installed in the vehicle. This tag includes the information of the Licence Plate along with the other necessary information. Surveillance Cameras keep a proper track of the positioning of the vehicles by interpreting the localized Licence place in an image from the arriving video frames. An RFID (Radio Frequency Identification Number) reader is installed in a location for the identification of the vehicle and it has a potential to interpret the information mentioned on the tag from a specific distance. Initially, the expenditure and the outlay of the proposed system were quite high, but with the advancement in the field of technology, the rate has gone comparatively much lower now. RFID System does not require the image of the vehicle to recognize the vehicles credentials, which eliminates any false recognitions. Hence, one can rely and trust on this particular system. The RFID System can be presented in a situation where a solemn answer to a problem is lacking and there is no acceptance of risk caused due to an error or in other words, there is no scope of an error [8].

1.2.1.1.2 Offline or Passive ALPDR System

In a Passive ALPDR System, the interpretation of the Vehicle Licence Plate takes place by capturing the images of the vehicles and then maintaining a database of these images in a centralized information server. Here, the recognition of the vehicle takes place by processing the image of the Vehicle Licence Plate. This process to a great extent, depends upon the quality of the image captured. Complications may arise due to noises in the image of the Licence plate and hence, this may lead in generating erroneous and inaccurate results.

1.2.1.2 Algorithms employed in the ALPDR System

ALPDR System is a system which is capable of recognizing the vehicle licence plate number from an image of the licence plate. But it has various stages which an image has to undergo to recognize the characters on the number plate.

In order to deal with variations among the characters in different Licence plates due to language, different jurisdiction, writing style or font difference, the segregated characters are required to go through few pre-processing that includes normalization and skew correction. Se we have some pre-processing steps that prove to be of great help in reducing the analytical and the computational duration before getting the final results. The plate image undergoes through the process of binarization and noises are reduced as much as possible in the preprocessing step

The flowchart below provides an overview of an ALPDR system [6].

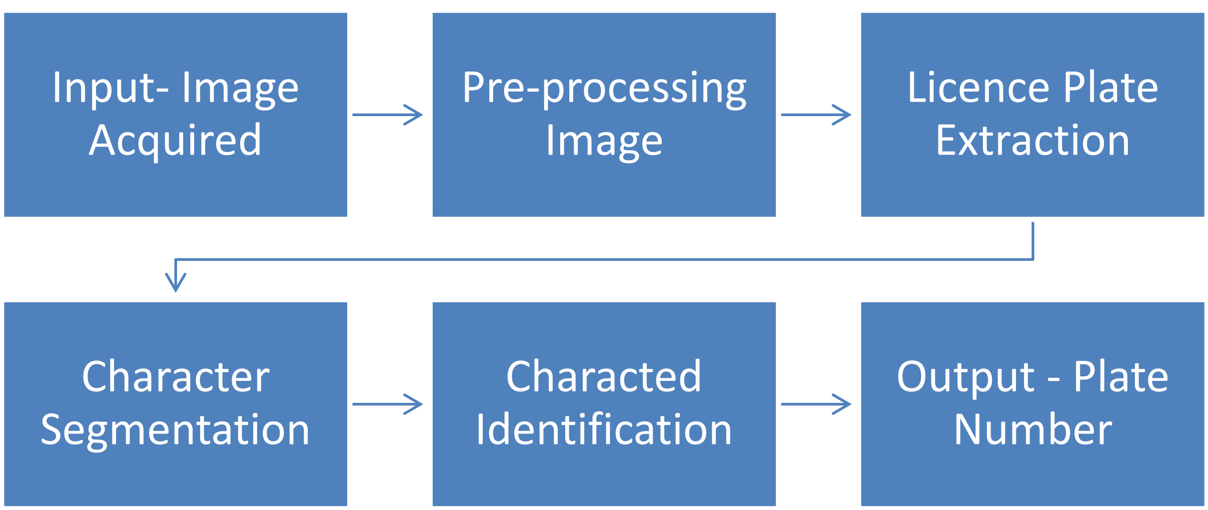

Figure 5: Flowchart explaining an ALPDR System

The following five steps are primarily taken into account by the ALPDR (Automatic Licence Plate Detection and Recognition) System to successfully identify a Licence Plate [9]:

1. Plate Localization: This deals with the identification, judgement and separation of the Licence Plate on the images processed.
2. Plate Inclination and Size: This accounts for the compensation of the distorted/skew of the Licence Plate and helps in the adjustment of the magnitude and the proportions of the requisite range.
3. Normalization: Here, in this step, the brightness and the contrast in the images generated are adjusted and altered.
4. Character Segmentation: This step implies heavily on the searching of single or individual characters scripted on the Licence Plates of the Vehicles.
5. OCR (Optical Character Recognition): OCR is basically defined as the automatic transformation (both mechanical and electrical) of the descriptive images of the text, either written manually or typed, frequently captured by the scanner into machine text which is editable, hence, changes can be made into it. It functions by the successful implementation of two basic steps: Training and Recognition. The image is taken as an input, the characters and numbers are segmented, and the features are extracted from the segments and then finally recognized by matching the existing templates from the database of OCR process.
    a. Training: The program is first trained with a set of sample images from database for each of the characters to pull out the important characteristics based on which next operation (the recognition operation) would be carried on.

b. Recognition: based on the closely matched template, the character is finally recognized and written to the output file.

1.2.1.3 Technological Requirements for the ALPDR System

ALPDR (Automatic Licence Plate Detection and Recognition) System has certain prime technological requirements given as:

1. The quality of the Automatic Vehicle Licence Plate Detection and Recognition System along with its functional and practical recognition techniques.
2. Camera quality and the quality of technological software for image acquisition.

If these recognition algorithms are implemented in a better manner, they will represent:

1. A hike in the quality of the ALPDR software
2. The rate of image recognition accuracy will be higher comparatively.
3. The image processing speed will be faster.
4. It will be able to handle a wider range of the image quality.
5. It will show its compliance to deal with a variety of plates.
6. It will witness tolerance power towards distortions of the input data.

In general, a single ALPDR (Automatic Licence Plate Detection and Recognition) System is able to examine the Licence Plates only of a particular country, since the geometrical arrangement of the Licence Plate along with the scripts, the font color, the font size, syntax and the direction, etc. are generally realm specific. If devoid of the prior awareness and information in respect to the Licence Plate geometry, i.e. the character allocation, the spacing between the characters, the dimension ratios, etc., the ALPDR System software would be unable to predict the Licence Plate in the image acquired or captured [10].

The figure given below provides the Plate Geometry and Basic Syntax of a Licence plate [11]

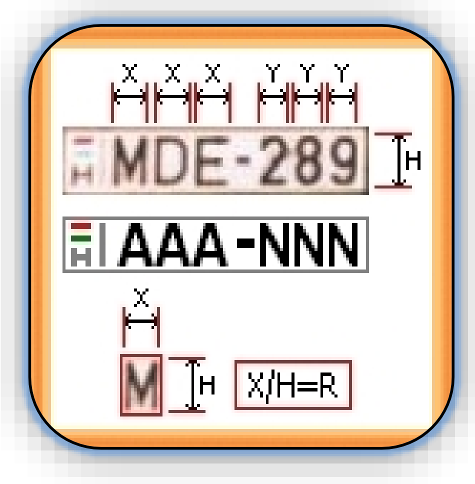

Figure 6: Plate Geometry and Basic Syntax of a Licence Plate [11]

Licence Plates are available in a wide range all around the world. These include [11]:

1. White Script on Black or a light background
2. Black Script on White or a dark background
3. Single Row Licence Plates
4. Multiple Row Licence Plates

In case, an ALPDR System is not able to make use of the information with respect to the Licence Plate Structure, then it withdraws itself from the supportive help resulting from the input data. This brings about a decrease in the accuracy of the ALPDR System. Without the utilization of the prior information of the License plate, the remaining part of the image recognition system considerably becomes more healthy and robust, which in turns give rise to many more challenges.

The prime image acquisition algorithmic technique determines the quality of the captured image of the plate through which the image detection software has to be employed. The better the quality of the captured image, the better is the accuracy of the resulted image.

A good quality captured image witnesses the following properties:

1. Decent Angular View
2. High Sharpness
3. High Developed Contrast
4. Good Spatial Resolution
5. Adequate Lighting Conditions

The following figures describes the problems encountered in the image quality:

Figure 7: Low Spatial Resolution

Figure 8: Blurred and Motion Blurred image

Figure 9: Low Contrast Images

Figure 10: Bad Lighting Conditions

1.2.1.4 Challenges faced by the ALPDR System

The attributes of the Licence Plates are maintained in a firm and specific manner in various developed countries. These attributes include the size and the color of the Licence plate, the number of lines included in the Licence plate, the font size, the font and the color of each and every character, the script used in the Licence plate, etc. [13].

The images below provide an overview of some of the standard Licence plates in some developed countries.

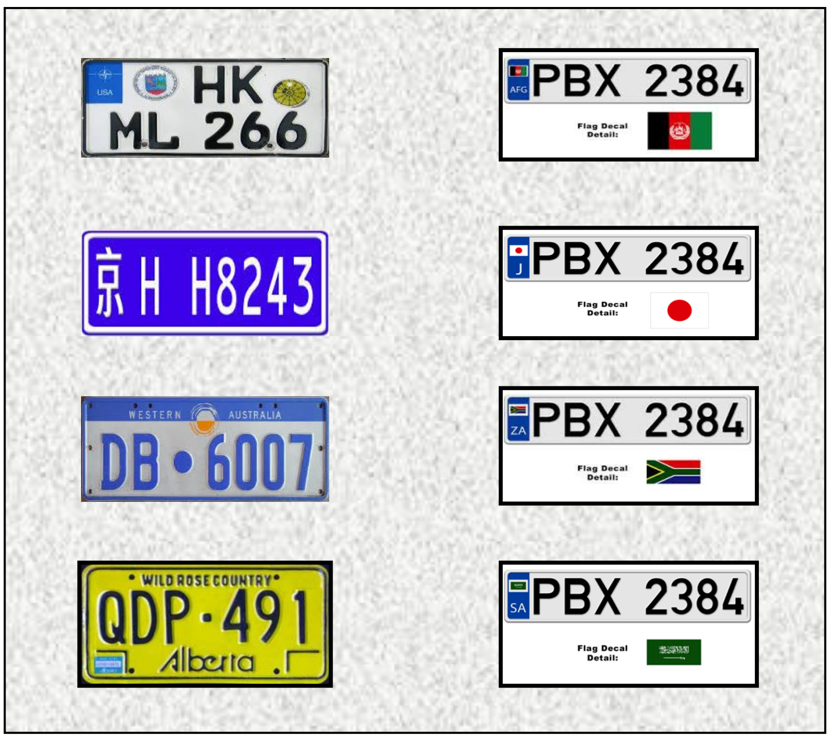

Figure 11: License Plates of Different Developed Countries [39]

Whereas, in developing countries, a standard practice for the Licence plate is still not employed among different states which results in causing the process of localization and the recognition of the Licence plate an exceedingly complex and complicated task. Also, the script used in writing the Licence plate is not universal throughout the country or in other words, multiple scripts are used. The images given below provide an overview of the Licence Plates highlighting the variations in the script, shape, font, size, etc.

Figure 12: Licence Plates in Developing Countries [39]

The various difficulties faced by the ALPDR System include [14]:

1. **Poor Image/ File Resolution:** This may arise on account of various reasons which include the distance of the Licence plate while taking the photograph, i.e. the Licence plate may be too distant which causes a decrease in the image quality or camera employed in capturing the images is not of high quality.
2. **Blurred Images:** The images here become motion blurred. The term motion blurred refers to the perceptible streaking of the moving objects in an immobile image or in a sequence of images, e.g. in a movie. This drawback primarily arises on account of rapid movement during the coverage or recording of an image, thereby resulting in creating disturbance in the image.
3. **Poor Lighting and Low Contrast Images:** This situation arises mostly on account of overexposure in the surroundings, reflection of various objects in the environment or shadows projecting on the licence plate.
4. **Object Obscure:** This happens when certain object or substance sticks on to the plate or a part of the plate, for example, dirt or tow bar wiring which causes complications in taking a clear image of the Licence Plate.
5. **Problems due to the difference in the Licence Plates:** The front and back reading of the Licence Plates are different in many jurisdictions. Some only require to put rear plates so the owner can install any custom characters to the front. This creates difference in licence plates in same vehicle.
6. **Change in the Angular View of the Camera produces Low Quality Images:** During the reading of the Licence Plate of the vehicle, the changes in the vehicular lane bring

about a change in the angular view of the surveillance camera and hence, results in low quality images.

7. **Trouble caused on account of different fonts used:** A different font is used on the Licence Plate of the Vanity Vans, which enhances the problem. However, various countries have completely boycotted this which has resulted in eliminating the trouble caused due to the employment of these dissimilar fonts.
8. **Lack of Coordination between different states in a country:** Sometimes, the vehicles from two different states or from different countries own the same Licence Plate number but the font and the script is different.
9. **Circumvention Techniques:** This technique increases the reflective properties of the script and develops a proxy setting through which it becomes difficult to trace the Licence Plate or to develop a high-level contract in the imaging which assists in coding the number. A plate cover or spray is employed for this technique.

Some of these drawbacks can be rectified through the software; however, those still left are transferred onto the hardware part of the scheme to find a solution for these problems. The complications that arise due to the objects obscuring onto the Licence Plate can be avoided by increasing the height of the surveillance camera. However, it gives birth to other difficulties, such as adjusting the amplified and enlarged skew of the Licence Plate [15].

Tow bars also causes obscuring in the characters of the Licence Plates of the Vehicles. Various small-scale systems account for errors in the Licence Plates. When certain vehicles are given the admittance into restricted areas, there is a possibility of an error rate with a single character. The reason behind this may be considered because an unofficial vehicle witnessing a similar Licence Plate is not considered something different and observed as quite simple. But, this kind of erroneousness and imprecision would not be appreciated in various applications of ALPDR System.

1.2.2 VSDR System

Vehicle Shape Detection and recognition is the second part of AVDR. The objective of this system is to recognize the shape of the vehicle. There are various types of shapes into which a vehicle can be classified. The various car classifications are Hatchbacks, Sedans, Crossovers, Sports Utility Vehicles (SUV), Vans and Trucks. These are the types which are used most often by the general public. This area has not been explored as much as the Licence plate detection. The reason for this is that only recognizing the vehicle shape does not give any unique feature of any vehicle. This approach combines vehicle licence plate detection with shape detection which helps to identify individuals for credibility.

The best angle to detect any vehicles shape is by looking at the side profile of the vehicle. Each and every class of vehicle can be distinguished by analyzing the image of that vehicle from side. The system recognises a pattern of the vehicle by recognizing the outer boundary of the vehicle.

1.2.2.1 Classification of Vehicle

The system implemented can detect three types of vehicle classes. Each class has specific differences which are defined below:

1. Sedan: Sedan is an automotive in a three-box design with A, B and C-columns and chief volumes explained in partitioned compartments for motor, traveler and freight. The traveler compartment highlights two lines of seats and satisfactory traveler space in the back compartment for additional travelers. The payload compartment is regularly in the

back, except for some back-placed engine models [30]. The image in figure 18 is one of the templates used by the VSDR system to recognise the class of the vehicle to sedan.

2. Hatchback: “A hatchback is an auto body arrangement with a back door that swings upward to give access to a load territory. Hatchbacks may have fold-down second column seating, where the inside can be adaptably reconfigured to organize traveler versus freight volume which it can haul” [31]. It is usually small in dimensions than a sedan or a SUV. Figure 18 is a typical template for a hatchback.
3. SUV: According to the Merriam-Webster dictionary, a "sport utility vehicle" is "a rugged automotive vehicle similar to a station wagon but built on a light-truck chassis". [32] The "SUV" term is defined as "a large vehicle that is designed to be used on rough surfaces but that is often used on city roads or highways.” [33]. Figure 18 is an example of template for an SUV.

1.2.2.2 Challenges faced by VSDR System

Challenges with VSDR system are similar to many applications that use Images for extracting information.

1. Inconsistent lighting: In the real world, during the day the light intensity varies. Natural light is not as intense at dawn and dusk as it is intense around noon hours of day. This causes the image of the same object at different times of day to be inconsistent in brightness. This also effects the background of the image. Because of intense light sometimes it is difficult for the algorithm to detect the edge of the vehicle. If the algorithm is unable to detect the edge then it will not be able to detect the shape of the vehicle.

2. Inconsistent background: For VSDR system to work correctly, the background has to consistent with all the images. This is necessary as VSDR system uses the background subtraction to get the object in the image. If the background is constantly changing then the VSDR system will not be able to get the desired output.
3. Over shadowing: Shadows cause a major problem for extracting information from image. Shadows created by the vehicle on the pavement also cause the background of the image to shift. The larger the shadow of the vehicle, more will be the inconsistency with its shadow. In a controlled environment the lighting can be controlled, hence the shadows can be controlled. But in an open setting these shadows cause a big issue in extracting information from the image.
4. Classification of vehicles: VSDR system classifies the vehicles into 3 different categories i.e. Sedan, SUV and Hatchback. But there are more categories of vehicles on road. Sedan and coupes have similar designs, so these are categorized into one class i.e. sedan. SUV, van and crossovers also have similar designs. They essentially have a flat back door and high ground clearance. So it is arguably difficult to categorise these into different classes. Hatchbacks have similar designs to SUVs, but are mostly smaller in dimension, so categorising them separately is easy. But, recently mini SUV category has also seen a boom which can also be falsely called a Hatchback.

1.3 Applications of the AVDR System

AVDR System finds applications in various fields which are described below [12]:

1.3.1 Parking Automation and Parking Security

This application provides mechanization in the efficient management of ticketless parking, accessing the parking mechanism, providing guidance in terms of parking location, preventing car robbery and theft, fraud caused on account of tickets exchanged or "lost tickets", generating a fully automatic payment procedure. In addition to this, the face image of the driver captured proves to be beneficial in preventing the car hijacking to a great extent.

1.3.2 Access Control

This application can be implemented through the identification of the Licence Plate and shape of the vehicle, thus providing security and safety, event management and logging, etc. Through the successful implementation of this application, the authorized members are provided with the facility of automatic door opening which provides assistance to the security guard on duty.

1.3.3 Tolling or Motorway Tolling

On a Toll-Road, the travel fee or the toll fee is calculated considering the vehicle number and this generates the toll ticket. This application takes advantage of AVDR systems as they can recognize the vehicle rapidly, hence decreasing the time to enter the toll road for the passengers of vehicle.

1.3.4 Law Enforcement

AVDR System can be used by various law agencies and participates actively in the law enforcement activities. Traffic management which includes to keep check on any traffic violations such as over speeding can be managed by this system. This system can also work actively with national database to raise alert for any vehicle which is involved in any type of criminal activity.

1.3.5 Better Traffic Management

AVDR Systems can be used to calculate how much time a specific vehicle is taking to travel between any two intersections. Thus gives the duration time information which can be used to find if there is any congestion on that particular road. By analyzing the time the traffic management system can control the traffic effectively and swiftly to reduce congestion.

1.3.6 Border Control

The main reason of concern of any border control post is illegal border crossing. This can be minimized by effectively and quickly identifying the vehicles used in such activities. AVDR system can help in identifying the vehicle as it approaches the border security officer, hence providing him with information regarding the vehicle and the owner. This helps by raising an alarm for any suspicious vehicle. This vehicle could be involved in smuggling of illegal goods across border or worse, terrorism.

1.3.7 Other Applications

In addition to the above mentioned applications, AVDR System helps the society in various other ways. These include:

1. Traffic Control
2. Marketing Control
3. Airport Parking
4. Solving issues of Stolen Vehicles
5. Providing assistance in Travelling

CHAPTER 2: LITERATURE REVIEW

An image extraction algorithm in Licence Plate Detection and recognition System was proposed by Salah Al-Shami et al [16]. Here, the optical character recognition is being implemented by assigning weights to characters. The tests were performed on real world licence plate images. Character recognition is undoubtedly a difficult task, and many researchers have worked with full authenticity to sort out this problem. This process depends upon manual selection of each line of character and also each character individually. This manual selection of characters is crucial to this technique as it produces ideal conditions to get accurate character recognition. Different stages are incorporated into this recognition plan of a character. Characterization depends on definitive features of that character which are stored earlier to compare. These characters are matched to the manually selected characters to get results. In KSA (Kingdom Of Saudi Arabia) this technique was utilized on a few datasets in License Plates. Consequently, the generated results showed the precise and the productive way of the proposed technique in contrast with the traditional proposed plans.

S. Kranthi et al. [17] proposed the technique for the recognition of character in the licence plates referred as Automatic Number Plate Recognition (ANPR). In the proposed work, a remarkable "feature-based Licence plate localization" strategy has been thought about which basically focuses on two brief strategies. The first strategy incorporates the edge detection mechanical technique. The second strategy involves applying various filters on the image to improve the image quality. These strategies were implanted to build up the Automatic License Plate Detection and Recognition framework in a superior way. ANPR is used in various applications which use cameras to keep track of vehicular activities. The proposed systems applications are demonstrated in the effective law authorization. In this approach cameras are used to take pictures of the vehicles. These pictures are of the rear end of the vehicle which contains the licence plate. By applying the algorithm first the licence plate is localized from the image and then the character recognition algorithm is implemented to get licence plate information. This task is implemented effectively by the help of high definition cameras so that the image quality is high so that data can be extracted out of the image.

Bolotova Yu.A. et al [18] proposed a hierarchical temporal memory model to achieve good recognition rate of licence plates. To identify a vehicle effectively from images is not an easy task to implement. The main outlining procedures involved in licence plate recognition are localization of the plate on the image, then successfully performing the character segmentation on each character and then implementing optical character recognition. Images gathered are not always in ideal conditions. Images in which the licence plate view is being partially obstructed by some object and some images taken at some angular inclination. This paper focuses on implementing a technique which will filter the images before performing any other task on the image. The images which go through the first process are then processed to do the character segmentation. Then the character recognition is performed by hierarchical temporal memory model. Filtering the images which were ideal to this approach helped immensely in the effectiveness of the rest of the technique. If the angular images are taken into consideration, the effectiveness of character segmentation decreases. Dividing the algorithm into different components helps in identifying the images before the other components can be triggered. This purposed method for identification of characters from licence plate yields better result than performing the same technique without the pre-filtering component.

Amr Badr et al [20] proposed and presented an ANPR (Automatic Number Plate Recognition) System, which performs plate localization and character recognition. This method uses different techniques for the plate localization and character segmentation as well as recognition. Edge detection and morphological techniques are used to localize the licence plate from the image. Whereas the character segmentation and recognition are done by the help of artificial neural networks. This system also has a few drawbacks such as poor image quality, different angles of inclination in the image, bad lighting and low contrast to name a few. This system is only for images and not for continuous videos. And the images had to be taken while the vehicle is at a full stop, so that the image is not blurred which will result in poor recognition rate. Even the skewed images are also not recognized as the character segmentation is not effective. The main focus of this method was to study the results of this algorithm on random images and not to get the most accurate results.

Nima Asadi [21] conducted a comparative study on the protocols and the methodology of the Automatic Licence Plate Recognition Algorithms and Techniques. ALPR (Automatic Licence Plate Recognition) System serves effectively in the improvement of traffic, speed control system and security management in the metropolitan cities. Several techniques and systems have been developed and introduced in the past few decades. These systems have basically focused on developing a better version of earlier systems and provide solutions for issues and the drawbacks encountered in the recognition system of the number plates. At this particular time, the constant increase in the count of vehicles makes it a difficult task to manage transportation system effectively. Henceforth, this all accounts for a need of the acknowledgment of the number plate of the vehicles keeping in mind the end goal to deal with the developing issues and complexities experienced in the everyday life and to bargain adequately with the movement administration, auto parking garage administration, vehicle toll gathering framework, infringement of movement standards, outskirt checkpoints, controlling the criminal exercises, similar to robberies and so forth.. The current paper presents four techniques for the Vehicular Licence Plate Recognition, a comparative study for these technical methodologies have been provided along with their drawbacks. In the initial technique, global statistical characteristics (like density gradient and density variance) and arbitrary Haar-like features are taken into consideration to carry out the detection process in a fast and an accurate manner. The isolated results with high accuracy are used to develop the next layer of the classifier. In the next method, a planned approach is presented considering the boundary-line approach. To complete the detection process rapidly, the current method makes use of two algorithms simultaneously, i.e., Hough Transform Algorithm and the Contour Algorithm. These two algorithmic provide the character recognition by calculating the breadth to height ratio and applying a horizontal score to the character regions. Further perfection in the recognition process of the candidate location in the Licence plate is brought about by performing the projection process horizontally or a horizontal projection approach is employed for character segmentation. In the third method, a mean-shift approach to each pixel in the spatial-range domain is applied, in order to determine the convergence point for every single pixel. The candidate regions are identified through these convergence points. The classification between the candidate regions of the number plate and the background is brought about through certain other techniques, which are aspect ratio test, edge density gradient and the rectangularity test. In the last and the final step, the character identification in the Licence plate candidate region is brought about by Mahalanobis classification system. To bring about a decrease in the count of the candidate regions, morphological techniques are taken into consideration. Mahalanobis System makes use of three steps:

1. Acquiring the contrasting features of the images through morphological operations
2. Recuperation process of the character segmentation is done through a reconstruction protocol.
3. A specific character identification technique is used to provide authenticity to the Licence plate in terms of the characters.

Lastly, a comparative analysis is provided between these four techniques. The result further revealed the inadequacy of the first method, since it requires a large memory space, therefore not feasible for the embedded systems, and also time-consuming, hence not suitable for the real-time system. The second technique is able to identify the background matters due to the presence of parallel lines. The third approach suffers a drawback with the vehicle that show a similar color as that of the Licence plate, and also with the snapshots having complex color. The final and the last step witness the low accuracy and the slow speed fault. Hence, the proposed work presents a comparative study on the protocols and the methodology of the Automatic Licence Plate Detection and Recognition (ALPDR) Systems in an efficient manner.

Thanongsak Sirithinaphong and Kosin Chamnongthai [22] proposed an algorithm for the recognition of Licence Plate in an automatic vehicle parking system. The successful detection of vehicle Licence Plate in automatic vehicle parking system is indispensable task. Detection of Licence plate at the at the Entrance gate of the parking system is vital as the license plate holds the distinct information with respect to the car. The current paper presents the Licence Plate Recognition in an automatic parking system by the application of the patterns of the number plate. The experimental results demonstrate the accuracy and the robustness of the recognition system in respect to the environmental discrepancy. Here, the motor vehicle laws and regulations in addition to the four layers BP (backpropogation) neural network algorithm has been taken into consideration to bring about the smooth functioning of process of identification of the vehicle number plate. The identification of the candidate regions in the vehicle number plate is carried out on the basis of the regulation of the plate, which primarily consists of the script, the color, the font, the font size, the pattern followed by the script and the count of letters, whereas the identification process through the implementation of neural network algorithm involves a simple rule, i.e., the candidate region which includes the alphabets and the numbers similar to the one justified by the motor vehicle regulation will be certified as a Licence plate region. The analysis carried out on the images of around seventy cars within an automatic parking system revealed the image extraction rate by 92%.

Lisheng Jin et al [23] proposed an algorithm for the identification of the Licence plates in the residential areas of China. Hence, to carry out this recognition process in the vehicular Licence plates, application software was constructed. The images acquired are preprocessed through certain parameters, like density gradient, middle value filters and the edge detection in order to bring about the extraction of the number plate location. The localization process proceeds by making accurate calculation of the edge points, the distance of the number plate dimensions and the total count of the lines holding the edge points. Next, the characters or the letters scripted onto the Licence plates were split by the process of segmentation. Character recognition is brought about by applying two approaches, which include the statistical character technique and the structure character technique. The characters that show a low level of distinction are provided with the building of a template library. The analytical results revels the accuracy of the character recognition to be around 92%, again the number of images were not specified. The protocol was presented for the recognition of the Chinese vehicle number plates.

Tran Duc Duan et al [24] proposed an Automatic Vehicle Licence-Plate Recognition System. In the present scenario, the boundless increase in the count of vehicles makes it impossible to manage the transportation system efficiently. . Due to the enormous increase in the count of vehicles, metropolitan cities focus on the development of automatic systems for traffic signaling and management. One of such essential system is the VLP (Vehicle Licence Plate) recognition system which captures the vehicular images and reads the Licence plate automatically. In the proposed research work, an automatic system for Vehicle Licence Plate (VLP) Recognition has been demonstrated through the implementation of ISeeCarRecognizer system, which shows the capability to read the Vietnamese Vehicle Licence Plate numbers. The ISeeCarRecognizer System basically includes three approaches; these are VLP detection, character segmentation on the number plates and character recognition of the number plate. In the initial module, a planned approach is presented considering the boundary-line approach. To complete the detection process rapidly, the current method makes use of two algorithms simultaneously, i.e., Hough Transform Algorithm and the Contour Algorithm. These two algorithmic approaches provide the character recognition by calculating the breadth to height ratio and applying a horizontal score to the character regions. Further perfection in the recognition process of the candidate location in the Licence plate is brought about by performing the projection process horizontally or a horizontal projection approach is employed for character segmentation. In the last step of the module, OCR (Optical Character Recognition) is implemented through the application of Hidden Markov Model. The results analyzed were demonstrated on two empirical sets of images in VLP (Vehicle Licence Plate) System and was found applicable and effective in toll collection systems and on the Vietnamese Vehicle Licence Plate images. It show its robustness in dealing with scratched, scaled, minor, unclear or blurred images and can also deal well with the multiple number plate images in a single snapshot and can work on various kinds of number plates, e.g., car, bus, truck or motorbike. But it faces certain drawbacks while dealing with the poor quality image recognition process.

Fredrik Trobro [25] proposed an approach for the automatic identification and recognition of the vehicle Licence plate in the real time systems the past few years, keen interest has been witnessed in the systems that account for detects and recognizes Licence Plates automatically. Various accessible approaches works effectively only on a single image while some other in order to capture a good quality and a still image requests the vehicle stoppage in front of the gate. The proposed thesis presents an approach making the processing of 25 images per second a possible task and is able to recognize the script and text of any font size, angle and location of the Licence plate, thereby reducing the bad impact caused due to a single image and vehicles can be permitted to drive past the camera without any obstruction and interference. An algorithm with the name, Stauffer Grimson has been applied in the current research that allows the system to successfully identify for the non-stationery or continuously moving objects on the Licence plates and to reach up to the obligatory image processing speed. This algorithm primarily works for the background estimation and provides tracking of various color values for each pixel present in the set. Hence, it can distinguish the leaves swaying with the wind by separating the color of the leaves and sky as the background. The prime technique for the recognition and the identification of the vehicle Licence plate includes a simple, computational and economical approach with the name connected component labeling algorithm which is capable of inspecting a connectivity of four pixels [26]. This algorithm works with the aim of determining the segmented areas of the same color, enclosed by the pixels of opposite colors, for example, a white scripted Licence plate surrounded by a black color border. Here, OCR (Optical Character

Recognition) Algorithm has also been considered which provides pixel-by-pixel comparison of the images. The results computed through a real-life test operating for twelve consecutive days demonstrated and revealed the identification rate of around 80%. There was no observance of false identification in the rate analyzed since each image in the database included a valid Licence plate number. Hence, the proposed thesis presented its benefits not just on all the frames and angles in the video streams but also on the motionless separated images within an Automatic Licence Plate Recognition system.

The following are the papers which were most relevant to the car shape detection and recognition.

T.R. Lim and AT. Guntoro [35] purposed the approach that depicts an auto acknowledgment framework utilizing a camera as sensor to perceive a moving auto vehicle. There are four fundamental stages in this procedure: object detection, object segmentation, feature extraction using Gabor filters and Gabor jet matching to the car database. This approach uses Gabor filters to extract features usind 2-D sine wave. The images used to perform experiments were taken in a controlled environment in a basement. The lighting was optimal and consistent for all the images. The foreground which consisted of car was relatively brighter than the background wall. The main focus in this approach was in template matching. In this research, three types of vehicle shapes are being used i.e. pickups, vans and Sedans. There are four templates used for each type of shape. A total of 12 templates were being used. This experiment was done on 44 unknown objects. The framework accomplished a normal acknowledgment rate of 93.88%.

David Santos, Paulo Lobato Correia [36] developed a system which can recognise car based on its backlights and rear view features. This paper presents two auto recognition strategies, both depending on the investigation of external feature components of the vehicle. The first strategy depends on the state of the auto's rear perspective, investigating its measurements and edges. Second strategy utilizes the highlights registered from the tail lights of an automobile. It recognises the pattern and placement of the taillights with respect to the licence plate in the image. This technique takes advantage of fact that rear end of an automobile is unique for each make and model. As there is no public database of images available for this specific application, the creators built a dataset of their own. A video was hot at the entrance of a parking facility which had 18 automobiles entering that facility. 40 distinct images were taken out of that video of those 18 vehicles which were of different make and model. The results of the experiments show recognition rate is 44 % utilizing just shape highlights. Then again, construct just in light of the extricated backdrop illumination includes the framework accomplished a right recognition rate of 72%, demonstrating a superior recognition execution. This approach is also focusing on security applications as it stating to use this approach with licence plate extraction.

CHAPTER 3: METHODOLOGY

ALPDR and VSDR systems have been explained separately. Each system has an independent control unit, which will work separately to give us the desired output.

3.1 ALPDR system

Dataset:

ALPDR System is developed for a specific application in the University. The dataset used for this System is gathered in University premises, by the consent of the University. This is done because there is no universal dataset in which this algorithm can be applied to get the accuracy. All the previous researches have been done using their own datasets which is not available to use for our algorithms. Sample Images of dataset are in Appendix 3.

The methodology implemented in the proposed project comprises of four main steps which are mentioned below [27]:

1. Pre-processing Stage
2. Licence Plate or Number Plate Localization
3. Character Segmentation
4. Optical Character Recognition

3.1.1 Preprocessing Stage

The Preprocessing technique for the Licence Plate localization consists of the performing the following tasks in order to achieve the desired image.

3.1.1.1 Wavelet-based De-noising

A wavelet is a wave-like oscillation along with amplitude which starts at zero, then increases and again comes back to the initial zero.

De-noising is defined as the process of construction of a signal taking into consideration a noisy one. Various de-noising scheme are taken into account for the successful elimination of noise although conserving the initiative data and certain other crucial constraints of the image, e.g., contrast, brightness, background, edge, color intensity, etc.

The wavelet de-noising process implemented in the current proposal has been discussed below:

1. A wavelet transform is applied to the noisy signal in order to generate the noisy wavelet coefficients, up to a certain level which is able to figure out and differentiate the occurrence of PD (Partial Discharges).
2. An appropriate threshold limit is selected at each stage along with a suitable threshold method (i.e. either hard or soft) for the successful removal of noise.
3. Application of IWT (Inverse Wavelet Transform) of threshold wavelet coefficients for acquiring a de-noised signal.

It has been demonstrated in the previous researches that hard thresholding technique generates superior signal with respect to the noise ratio but here, in the current proposal, soft thresholding method has been given priority.

3.1.1.2 Conversion of image to Gray Scale

In the present step, all the RGB colour components, i.e., the Red, Green and the Blue are estranged from the 24-bit colour value of each pixel (i,j), in order to calculate the 8-bit gray value. This is performed by the implementation of the following formula [40]:

$$Gray\ (i,j) = 0.30*R(i,j) + 0.59*G(i,j) + 0.11*B(i,j)$$

3.1.1.3 Applying the Weiner Filter

The Weiner Filter is defined as the mean square error optimal filter and serves to minimize the MSE error caused due to the process of inverse filtering and noise smoothing between the probable random process and the preferred method. The main application of this filter is in signal processing where it helps to generate an average targeted random process through the implementation of LTI (Linear Time Invariant) filtering. The Weiner Filter serves as an optimization filter for the images which faces degradation on account of additive noise or blurred images. For calculating the Weiner Filter, the signal and the noise process are considered as second-order stationery and only those noise processes are taken into consideration which have mean to be equal to zero. It primary application is in the frequency domain and hence, it is given by the following formula:

$$G\ (u,v) = H^{*}(u,v)\ P_S\ (u,v)/\ H(u,v)^2\ P_S\ (u,v) + P_n\ (u,v)$$

Here,

H (u,v) denotes the Fourier Transform of the Point Spread Function (PSF)

$P_S\ (u,v)$ denotes the Power Spectrum of the Signal Process, and

$P_n\ (u,v)$ denotes the Power Spectrum of the Noise Process.

3.1.1.4 Enhancement of the Image Contrast

This can be achieved through the Histogram Equalization Technique, where the complete count of the image pixel is denoted with the term n and those in the gray level, ***k*** is defined as ***nk***. Therefore, the probability of occurrence of the image in the gray level ***k*** is defined as:

$$P_{K\,-}\,nk/N$$

3.1.2 Licence Plate Localization

The primary step in the Licence Plate Identification System includes the localization of the Licence plate. The image captured constituting the complex background is filtered in this step and the resultant image provides the number plate image with high contrast regions. Due to the presence of the ambiance in the snapshots the scene becomes complex. There is a need to consider a specified frame, so that one can focus on the specific images, this can be achieved by excluding the background from the image. Hence, an appropriate and specific window frame size must be taken into consideration. The window size is predicted by the probable dimensions of the number plate.

The proposed scheme comprises of two modules for the localization of the number plate: Rough Detection of the Number Plate regions and accurately localizing the Region of Interest (ROI). The vertical gradients proves beneficial in the rough prediction of the Region of Interest (ROI) and this rough generated ROI in turn is used to obtain the accurate Region of Interest (ROI) through the implementation of Wavelet based De-noising and morphological operators. The current method works by the application of Discrete Wavelet Transform (DWT) which works by highlighting the vertical edges of the number plate and repressing the background noise. After the completion of this step, the extraction and the localization process of the Licence plates occurs by orthogonal projection histogram analysis through morphological operator. By the proposed scheme, the number plates of a variety of vehicles can be extracted (both front and back). The results simulated through the analytical and experimental analysis reveal a good quality of localization results with small runtime and high accuracy in the detection rate.

3.1.3 Character Segmentation

The process of character segmentation acts as a link or a connection between the localization process of the number plate and the Optical Character Recognition (OCR) modules. This step implies heavily on the searching of single or individual characters scripted on the Licence Plates of the vehicles. The prime function of this step is to provide separation to the characters that are selected in the candidate region or from the extracted number plate, so that each character would be transmitted individually to the OCR scheme to carry out the process of recognition. “Basically, this process focuses on the histogram computation and thresholding but recent advanced protocol involves the implementation of the artificial neural networks” [7]. In order to carry out the segmentation process efficiently, there is prime requirement of normalized or standardized Licence plates, since various plates follow different font styles and also, the alphabets and the numeric formats are fancy. Therefore, the countries where the normalized Licence plates are absent, does not even have an efficiently running LPR (Licence Plate Recognition) System. In order to overcome this drawback, the government authorities in such countries should undertake an initiative with specific guidelines and make mandatory for all the drivers to include high security Licence plates in their vehicles.

After the completion of the localization process, one can process effectively towards the identification of individual characters. Since, a vehicular number plate comprises of the high intensity variation scripted region, (i.e. white script with black background and vice versa), this provides a base for the character segmentation process. However, a Licence plate sometimes holds the name of the state along with the different other text, there is a need to eliminate such text and words. Morphological operators are implemented for the elimination of the white regions that flee away the range rectification process, since sometimes the shadows and the text demonstrate similarity with the numerical characters. Finally, the extracted characters are passed onto the OCR (Optical Character Recognition) module.

The process of character segmentation is unique, novel and important in the ALPDR (Automatic Licence Plate Detection and Recognition) System since the functioning of all further processes depends upon it. Also, if the process of segmentation faces failure, then the character may not get divided decently into two sections, or two characters may inappropriately get merged together, which in turn causes a failure of the recognition process. If only one row number plates are provided consideration in the ALPDR (Automatic Licence Plate Detection and Recognition) System, then the process of segmentation works to identify the horizontal boundaries among the characters localized. The second stage in the segmentation process is the enhancement of the segmented characters. Since, the number plate includes the characters along with certain adverse rudiments, e.g. noise on account of shadows or defects in the cameras or other equipment, as well as undesired space on the character sides, therefore there is a need to remove these and extract out only the individual characters.

The extracted number plate region or the candidate region functions as an input for the segmentation process. Here, a coloured JPEG and binary image is taken as an input, hence, the initial step in the segmentation process includes the binarization of this image. The binary image obtained comprises of undesired regions which may obstruct the recognition process, hence, they must not be taken into consideration. The connected components concept is considered in order to remove the small areas out of the number plate space. Here, the components which comprises of the pixel value lesser than the specified threshold are transformed back to the background and thus, disregarded. Hence, what left is a comparatively moderate binarized number plate devoid of noise and undesired regions, and appropriate to carry out the segmentation process.

3.1.4 Character Recognition

The premium aim of this step is to provide classification and complete identification to the binarized images that comprises of the characters obtained from the number plate localized regions.

The figure given below describes the functioning of the OCR via flowchart:

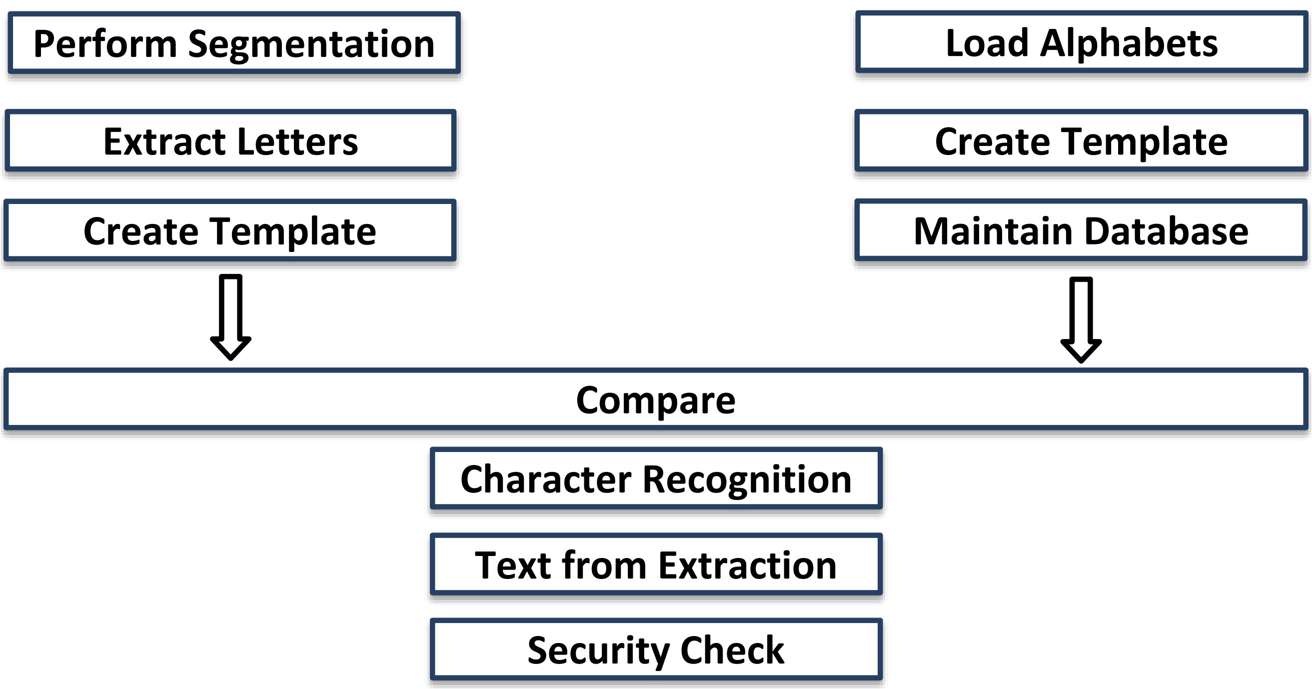

Figure 13: Flowchart representing the process of OCR

Following are the steps which result in Character Recognition:

1. Template Database: Production of format database is essential before the character recognition can begin. So according to the text style of the Licence plates, the database is

created. This database comprises of alphabets A-Z and digits 0-9. (See Appendix for the templates)

2. Comparing Segmented Characters After the templates are stacked in the memory, the ALPDR system compares each segmented character to every one of the templates and provide with the nearest positive value.
3. This process is repeated until all the segmented characters are recognised.

3.2 VSDR System

Dataset

The database which was created for the VSDRS system was collected in University of Windsor premises. To collect this data permission was taken from University of Windsor law office, on terms that the data will be solely used for educational purposes towards this thesis.

This database was gathered in the early hours of morning from 7:00 AM to 9:00 AM on various different days. This time was chosen because of the high amount of vehicles which enter the parking facility. It was perfect timing to get most volume of vehicles in small amount of time. No artificial lighting was used while shooting these images. Figure 14 shows the top view of the setup which was used in capturing the database. The figure consists of Entry Lane from where the cars enter to approach the Ticket booth right before the barrier. A camera was placed on the tripod across the ticket booth so that the side profile of the car could be taken. This camera was taking continuous video at 30fps and 1920 X 1080 resolutions. This video was then processed frame by frame and the particular frames in which different vehicles were present were then extracted. The sample images are in Appendix 3.

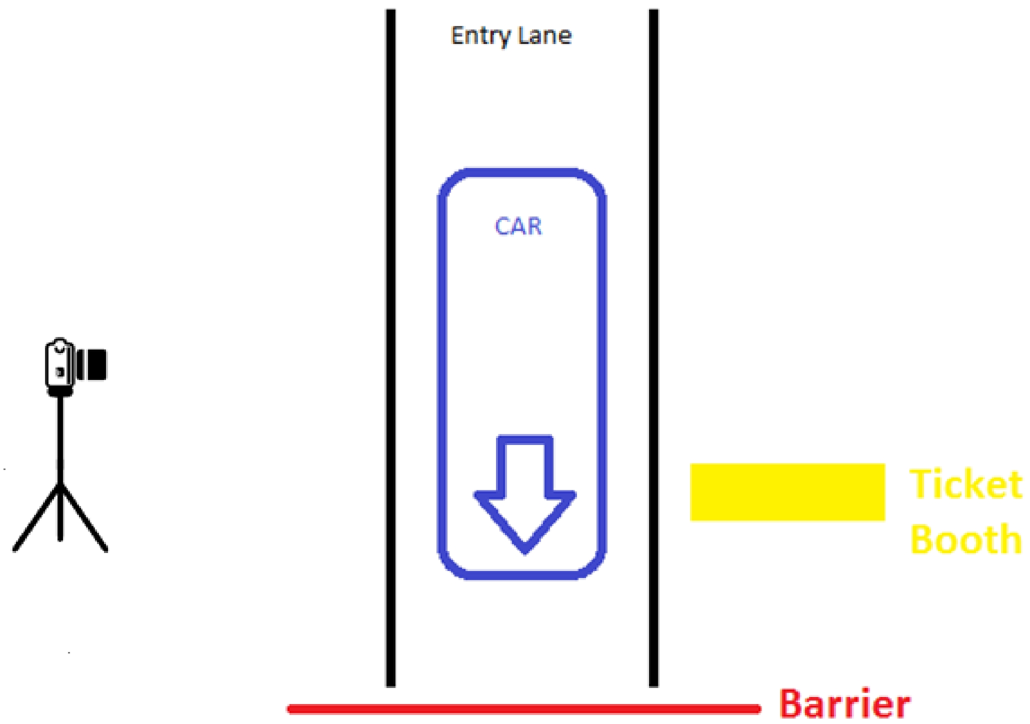

Figure 14 – Top View of Camera Setup at the parking facility used by VSDR System

Algorithm employed in VSDRS:

Once the database is been created, the images are processed before implementing the algorithm. This pre-processing is necessary to eliminate the noise surrounding the vehicle. This also helps in keeping the background of the image consistent throughout the database.

3.2.1 Pre-processing

Figure 15 shows the extracted frame of a sedan. The VSDR system works when there is a unicolor background in the image. With unicolor background, the edges of the vehicle are precisely visible.

Figure 15 - Extracted frame of Vehicle

All the images extracted were then processed manually to get every image to have same background of white color. See Figure 16 for the resulted image.

Figure 16 - Vehicle after converting the background with a Unicolor (white)

To get the shape of a vehicle we need two things, Foreground and Background. The image in in figure 16 and the background image is a unicolor image of same resolution as of the image taken. The various steps which are followed to identify a class of any vehicle are described below:

3.2.2 Normalising the image

The images were taken by a camera with native resolution of 1980 X 1080 pixels. At this resolution the computation time for the program can be very high. Also the space requirement for storing these images will be high. So to make the system faster and also require fewer resources the images were normalised to 640 X 360 resolutions.

3.2.3 Background subtraction

To generate the templates of different vehicle this system will subtract the background from the foreground. Figure 17 displays the result after background subtraction. Once the background is removed the resultant image is used to create a binary mask. This mask is used to create templates for different shapes. These templates are later used to get the closest match of the vehicle and determining the shape of the vehicle.

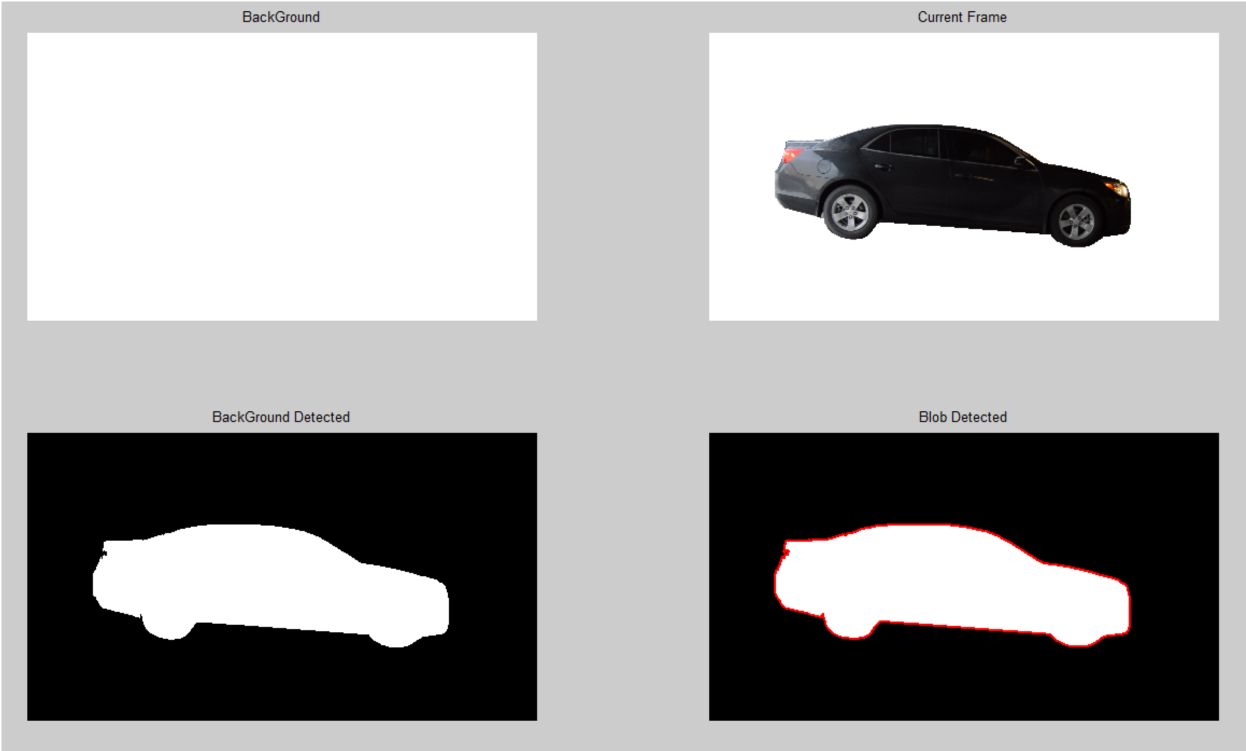

Figure 17 - Background subtraction and Blob Detection

3.2.4 Template Creation

After background subtraction the blob created is stored in the database for matching. A few templates are shown in Figure 18 below. The first column contains the templates for sedans, second for SUVs and third for Hatchbacks. These templates are stored in the memory so that they can be used to match them to the new set of images to recognise the shape of the vehicle.

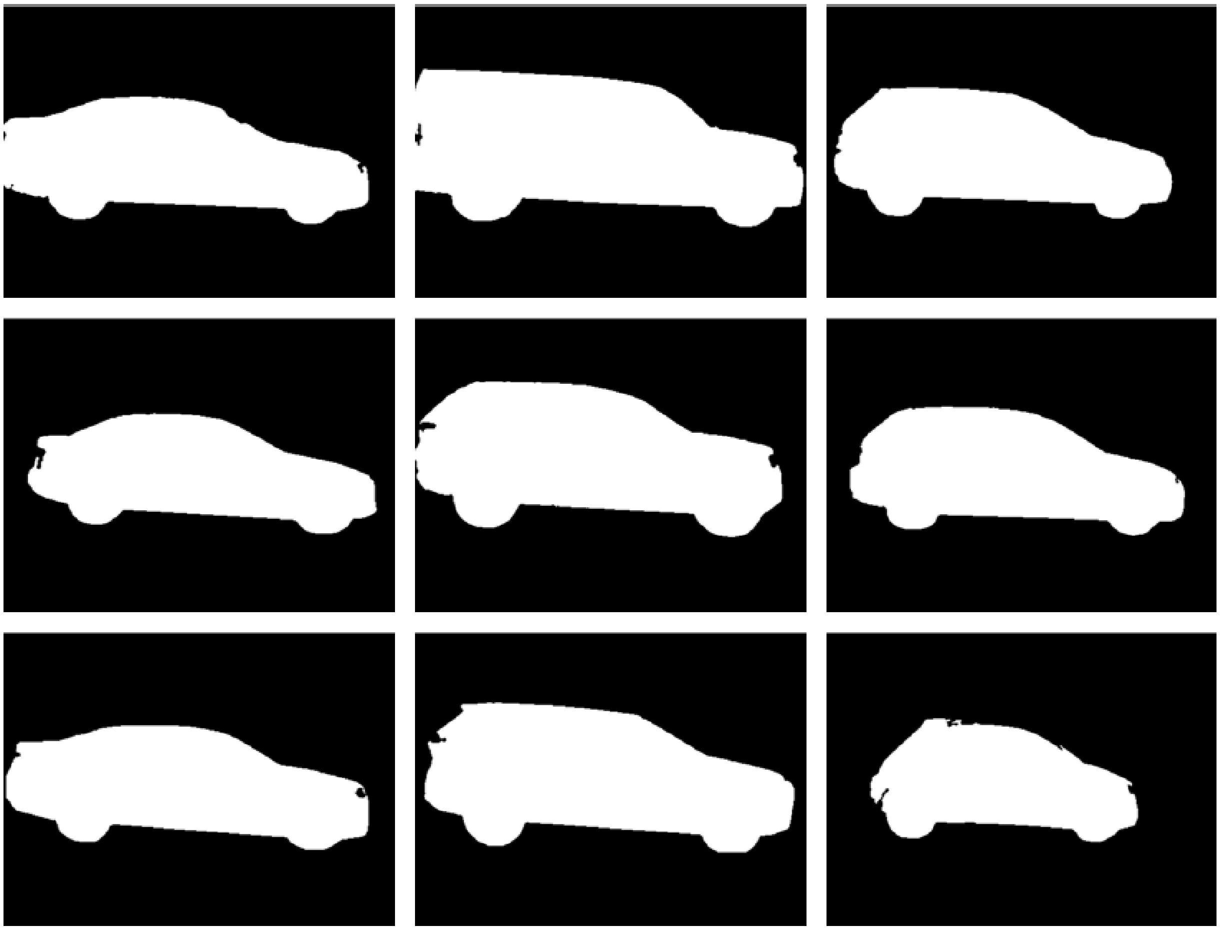

Figure 18 - Templates (i) Column 1 - Sedans (ii) Column 2 - SUVs (iii) Column 3 – Hatchbacks

3.2.5 Template Matching

The technique of binary masking is used to find the similarities between the loaded templates of Sedans, Hatchbacks and SUVs. The algorithm compares the current car with all the loaded templates of different shapes. This technique is similar to the OCR technique which is applied to recognize the character. The results are shown in the result section.

3.3 Results

3.3.1 Hardware Used

1. MATLAB version 2014a
2. Windows Operating System (WOS) 10
3. 1.8 GHz Intel "Core i5" Processor
4. 4 GB RAM

3.3.2 Input

The pictures given below provide the screenshots of the proposed scheme methodology and results simulated by APLDR system.

Figure 19 - Input Image

Figure 20 - Image obtained after wavelet de-noising using Symlet4 wavelet

Figure 21 - Converting the Image to Gray Scale

Figure 22 - Image obtained after erosion

Figure 23 - Image after Background Subtraction

Figure 24 - Number of the vehicle Recognized in the Result

3.3.3 Experiments

Comparison of this process cannot be done to other techniques as there is no set of unified rules or a unified dataset on which tests can be run. The following table will list all the images on which the tests were run. Last column shows us the accuracy of this system which uses Soft Thresholding technique in the preprocessing phase.

Table 1: Experiments

Input Number	1ST	2ND	3RD	4TH	5TH	6TH	7TH	No of correct	Percentage
BYDT 891	B	Y	D	T	8	9	1	7	100 %
AC 85013	A	C	8	5	0	1	3	7	100 %
BMJX 617	B	M	J	X	6	1	7	7	100 %
BXYY 291	B	X	Y	Y	2	9	1	7	100 %
BPWC 879	B	P	W	C	8	7	9	7	100 %
AVFL 214	A	V	F	L	2	1	4	7	100 %
BRLR 548	B	R	L	R	5	4	8	7	100 %
BUJL 383	B	U	J	L	3	8	3	7	100 %

BTHX 314	B	T	H	X	3	1	4	7	100 %
BYDT 423	B	Y	D	T	4	2	3	7	100 %
BKYD 911	B	K	Y	D	9	1	1	7	100 %
BYDT 819	B	Y	D	T	8	1	7	7	100 %
BKYD 911	B	K	Y	D	9	1	1	7	100 %
BPWC 879	B	P	W	C	8	7	9	7	100 %
BXEL 499	B	X	E	L	4	9	9	7	100 %
BVNK 986	B	V	N	K	9	8	6	7	100 %
BUNK 986	B	U	N	K	9	8	6	7	100 %
BSTY 229	B	S	T	Y	2	2	9	7	100 %
BAWP 571	B	A	W	P	5	7	1	7	100 %
AYDA 786	A	HY	D	A	7	8	6	7	100 %
BYDT 891	B	Y	D	T	8	9	1	7	100 %
BRLR 548	B	R	L	R	5	4	8	7	100 %
BVJL 383	B	V	J	L	3	8	3	7	100 %
BVMC 388	B	V	M	C	3	8	8	7	100 %
BXPS 184	B	X	P	S	1	8	4	7	100 %
BYDT 423	B	Y	D	T	4	2	3	7	100 %
BWTP 026	B	W	T	P	0	2	6	7	100 %
BLZP 686	B	L	Z	P	6	8	6	7	100 %
BMJX 617	B	M	J	X	6	1	7	7	100 %
BXYY 291	B	X	Y	Y	2	9	1	7	100 %
BDPF 005	B	D	P	F	0	0	5	7	100 %
BRXK 195	B	R	X	K	1	9	5	7	100 %
AWVM 174	A	W	V	M	1	7	4	7	100 %
BKLE 576	B	K	L	E	5	7	6	7	100 %
BNKF 642	B	N	K	F	6	4	2	7	100 %
BWHX 279	B	W	H	X	2	7	9	7	100 %
BTHH 992	B	T	H	H	9	9	2	7	100 %
BTHX 314	B	T	H	X	3	1	4	7	100 %
BTWV 396	B	T	W	V	3	9	6	7	100 %
BVMC 999	B	V	M	C	9	9	9	7	100 %
BDYX 587	B	D	Y	X	5	8	7	7	100 %
AZXR 671	A	Z	X	R	6	7	1	7	100 %
AZYM 679	A	Z	Y	M	6	7	9	7	100 %
AZYM 679	A	Z	Y	M	6	7	9	7	100 %
ATEL 529	A	T	E	L	5	2	9	7	100 %
AKXL 025	A	K	X	L	0	2	5	7	100 %
AZHB 448	A	Z	H	B	4	4	8	7	100 %
BSRR 480	B	S	R	R	4	8	9	7	100 %
BLJM 739	B	L	J	M	7	3	9	7	100 %

APLM 487	A	P	L	M	4	8	7	7	100 %
BXSB 566	B	X	S	B	5	6	6	7	100 %
BPSV 949	B	P	S	V	9	4	9	7	100 %
BVLV 525	B	V	L	V	5	2	5	7	100 %
BVLV 525	B	V	L	V	5	2	5	7	100 %
BMCM 508	B	M	C	M	5	0	8	7	100 %
BSET 296	B	S	E	T	2	9	6	7	100 %
BNTC 140	B	N	T	C	1	4	0	7	100 %
BVEY 094	B	V	E	F	0	9	4	7	100 %
BXHX 633	B	X	H	X	6	3	3	7	100 %
BVCC 862	B	V	C	C	8	6	2	7	100 %
BWTP 739	B	W	T	P	7	3	9	7	100 %
BTWV 047	B	T	W	V	0	4	7	7	100 %
BVPN 776	B	V	P	N	7	7	6	7	100 %
BWEX 889	B	W	E	X	8	8	9	7	100 %
BDPF 005	B	O	P	F	0	0	5	6	85.71 %
BXLE 576	B	X	L	R	5	7	6	6	85.71 %
BWHX 279	B	W	H	X	9	7	9	6	85.71 %
AWLF 209	A	W	L	F	2	0	N	6	85.71 %
BTWV 396	B	T	W	V	N	9	6	6	85.71 %
BVMC 099	B	V	M	C	9	9	9	6	85.71 %
BTTN 543	B	T	T	N	5	4	N	6	85.71 %
BWTP 026	B	W	T	P	8	2	6	6	85.71 %
BVNK 968	B	V	W	K	9	6	8	6	85.71 %
BCAY 963	B	C	A	Y	9	6	N	6	85.71 %
AZAE 976	B	Z	A	E	9	7	6	6	85.71 %
BSZZ 287	B	S	Z	2	2	8	7	6	85.71 %
BKFD 850	B	K	F	B	8	5	0	6	85.71 %
BKLE 056	B	K	L	E	9	5	6	6	85.71 %
BKLE 056	B	K	L	E	9	5	6	6	85.71 %
BRLW 549	B	R	L	W	5	4	9	6	85.71 %
BLKD 209	B	L	K	B	2	0	9	6	85.71 %
BVNK 037	B	V	N	K	0	N	7	6	85.71 %
BHAT 088	B	H	A	T	N	8	8	6	85.71 %
BVWH 593	B	V	W	H	5	9	N	6	85.71 %
BVFJ 380	B	V	F	J	N	8	0	6	85.71 %
B3NB 064	B	3	M	B	0	6	4	6	85.71 %
BPWC 879	B	P	W	E	8	7	9	6	85.71 %
BKYD 911	B	K	Y	B	9	1	1	6	85.71 %
BNHX 344	B	N	H	X	N	4	4	6	85.71 %
BRXJ 310	B	R	X	J	N	1	0	6	85.71 %

AWLF 209	A	W	L	F	2	9	9	6	85.71 %
BTTN 543	B	T	T	M	5	4	3	6	85.71 %
BJHW 578	B	J	M	W	5	7	8	6	85.71 %
BKMD 815	B	K	M	B	8	1	5	6	85.71 %
BSYM 851	B	S	Y	M	8	5	A	6	85.71 %
BCAY 963	B	C	A	Y	9	6	H	6	85.71 %
BTXR 236	B	T	X	R	2	N	6	6	85.71 %
BKTA 816	B	K	T	A	8	9	6	6	85.71 %
BTMS 241	B	T	M	S	2	4	9	6	85.71 %
ASAH 135	A	S	A	M	1	3	5	6	85.71 %
BYJJ 395	B	Y	J	J	N	9	5	6	85.71 %
BSEB 409	B	S	E	B	4	9	9	6	85.71 %
BRRS 004	B	R	R	S	0	9	4	6	85.71 %
BJLZ 178	B	J	L	2	1	7	8	6	85.71 %
BMVD 166	B	M	V	D	1	6	6	6	85.71 %
BSKY 087	B	S	K	Y	9	8	7	6	85.71 %
BJPN 046	B	J	P	M	0	4	6	6	85.71 %
BDKA 707	B	B	K	A	7	0	7	6	85.71 %
AMTU 570	A	M	T	U	5	7	8	6	85.71 %
BAPN 626	B	A	P	M	6	2	6	6	85.71 %
BRAY 105	B	R	A	Y	1	9	5	6	85.71 %
AXNV 710	A	X	W	V	7	1	0	6	85.71 %
BNTC 238	B	N	T	C	2	N	8	6	85.71 %
BPKF 037	B	P	K	F	0	N	7	6	85.71 %
BYJR 959	B	V	J	R	9	5	9	6	85.71 %
AK 18455	A	K	I	8	4	5	5	6	85.71 %
BWNR 438	B	W	N	R	4	N	8	6	85.71 %
BTPN 709	B	T	P	M	7	0	9	6	85.71 %
BNTC 140	B	N	T	E	1	4	0	6	85.71 %
BWNF 936	B	W	M	F	9	3	6	6	85.71 %
BWNF 936	B	W	M	F	9	3	6	6	85.71 %
DFK 2865	D	F	K	2	9	6	5	6	85.71 %
BXHC 947	B	X	M	C	9	4	7	6	85.71 %
BVWZ 331	B	V	V	2	3	3	1	6	85.71 %
AYDZ 755	A	Y	B	2	7	5	5	5	71.43 %
BJXU 005	B	J	X	U	0	8	E	5	71.43 %
ANTZ 029	A	N	T	2	9	2	9	5	71.43 %
BPNT 130	B	P	N	T	1	N	9	5	71.43 %
AZAF 933	A	Z	A	F	9	N	N	5	71.43 %
BKFD 833	B	K	F	D	8	N	N	5	71.43 %
AXNV 013	A	X	W	V	9	A	N	3	42.86 %

Following table tells us the Incorrect Instances of all the alphabets and digits:

Table 2: Incorrect Instances

Character	Number of Incorrect Instances
2	1
9	2
0	11
3	20
A	1
D	4
N	9
Z	3
C	2
B	2
H	2
Y	1
W	1

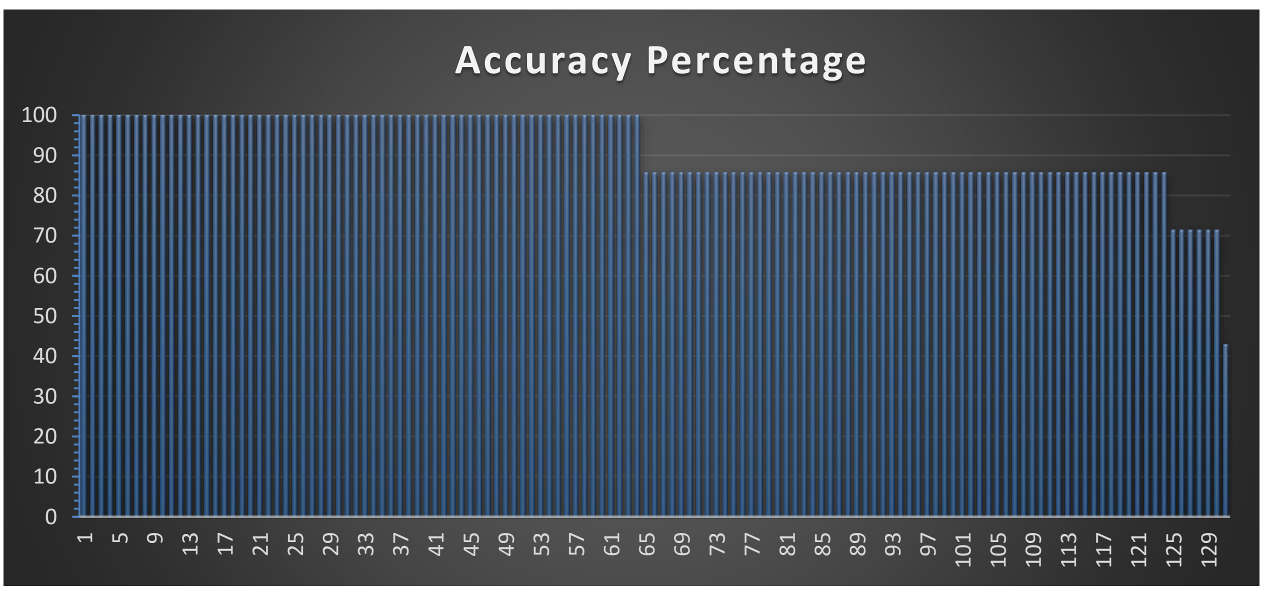

Figure 25 - Graph to show the Accuracy of OCR with respect to 130 Images

The following data is deduced from the experiments:

1. The experiments are done on 139 images.
2. Plate Localization is successful on 94.24 % of Images (131 out of 139)
3. OCR accuracy for all the Images is 93.34 %, out of which
    a. 64 Images have 100% OCR rate
    b. 60 Images have only 1 out of 7 character wrong
    c. 6 Images have 2 out of 7 characters wrong
    d. 1 Image have 4 out of 7 characters wrong

In VSDR system total of 102 images were used in experiments. The following are the categories:

1. Sedans : 58
2. SUVs: 38
3. Hatchbacks: 2

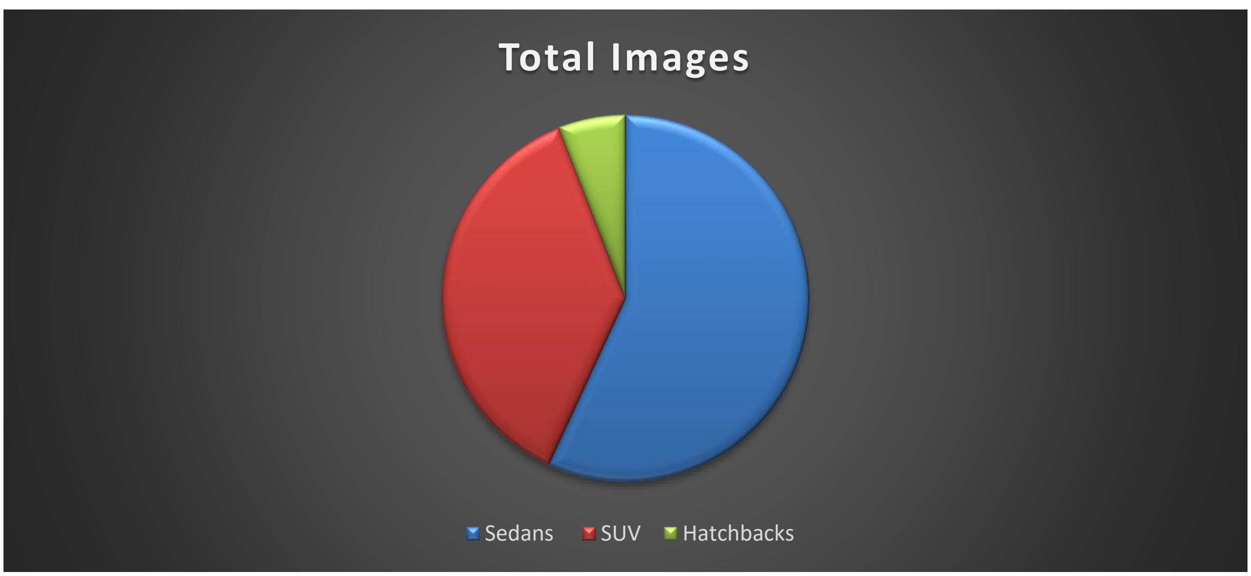

Figure 26 - Pie chart showing the proportion of images used in VSDR system

The following are the results to the VSDR system. Out of 102 images of vehicles 98 were categorised correctly with an accuracy of 96.07 %.

Table 3 - Experiment results for VSDR System

	Sedans	SUV	Hatchbacks
Total	58	38	6
No. of Correct	55	37	6

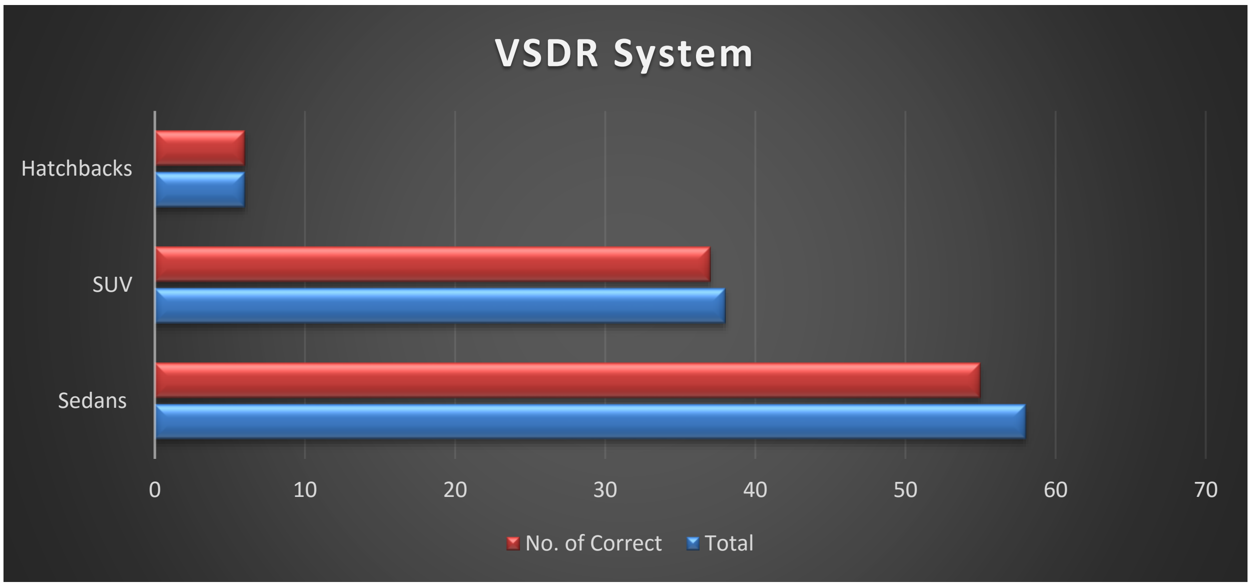

Figure 27 - Graph to depict the number of correct Image recognized

CHAPTER 4: CONCLUSION

AVDR scheme proves to be an effective tool undertaken by the legislative and consumer safety forums. It helps to mechanize the hectic, tedious and the physical procedure of the officers which they encounter and deal with in their regular day life, and serves to provide efficiency in the identification of the vehicles from hundreds and thousands of vehicles observed in the regular patrolling task. This data significantly improves the undercover competency of the law enforcement agencies and hence, proves beneficial in the intelligence and the analytical functioning. In the current approach, wavelet de-noising process with soft thresholding in preprocessing step generates a system for successful recognition of the Licence plate, and Binary masking of the templates of shapes can effectively recognize and classify a vehicle.

From the above results, we draw the following conclusions:

1. In order to carry the localization process of the number plate efficiently, the prime requirement is the presence of the proper edge between the vehicle Licence plate boundary and the background. This provides assistance to the Weiner filter in detecting the edge.
2. The camera must be located at a specific distance from the number plate, in order to provide a suitable range to the count of the pixels within the Licence plate region and to make them constant in nature.
3. The major drawback encountered in the character segmentation process is the presence of fancy scripts and formats which results in the creation of obstruction during the procedure.
4. In order to recognise the shape of a vehicle, the background has to be consistent and the edges should be clearly visible. The camera placement should be consistent with all the

images. As change in distance between the camera and vehicle can result in wrong identification of SUV to hatchback or vice versa.

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APPENDICES

Appendix 1: Character Templates

The following are the character templates which were generated by using the text styles of Licence Plates.

Table 4: Character Template

0		**1**		**2**		**3**		**4**	
5		**6**		**7**		**8**		**9**	
A		**B**		**C**		**D**		**F**	
F		**G**		**H**		**I**		**J**	
K		**L**		**M**		**N**		**O**	
P		**Q**		**R**		**S**		**T**	
U		**V**		**W**		**X**		**Y**	
Z		**0 Fill**		**4 Fill**		**6 Fill**		**6 Fill**	
8 Fill		**9 Fill**		**9 Fill**		**A Fill**		**8 Fill**	
D Fill		**O Fill**		**P Fill**		**Q Fill**		**R Fill**	

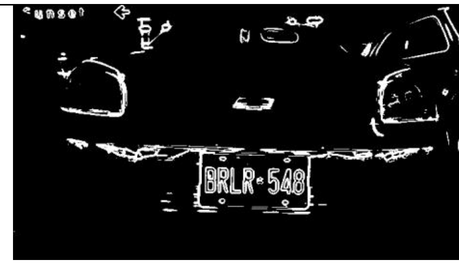
Appendix 2: Pre-processing Demonstration

The following are the different stages of the Images as it goes through the step of the algorithm.

These are grouped together to better demonstrate the process which is happening.

Table 5: Preprocessing Demonstration

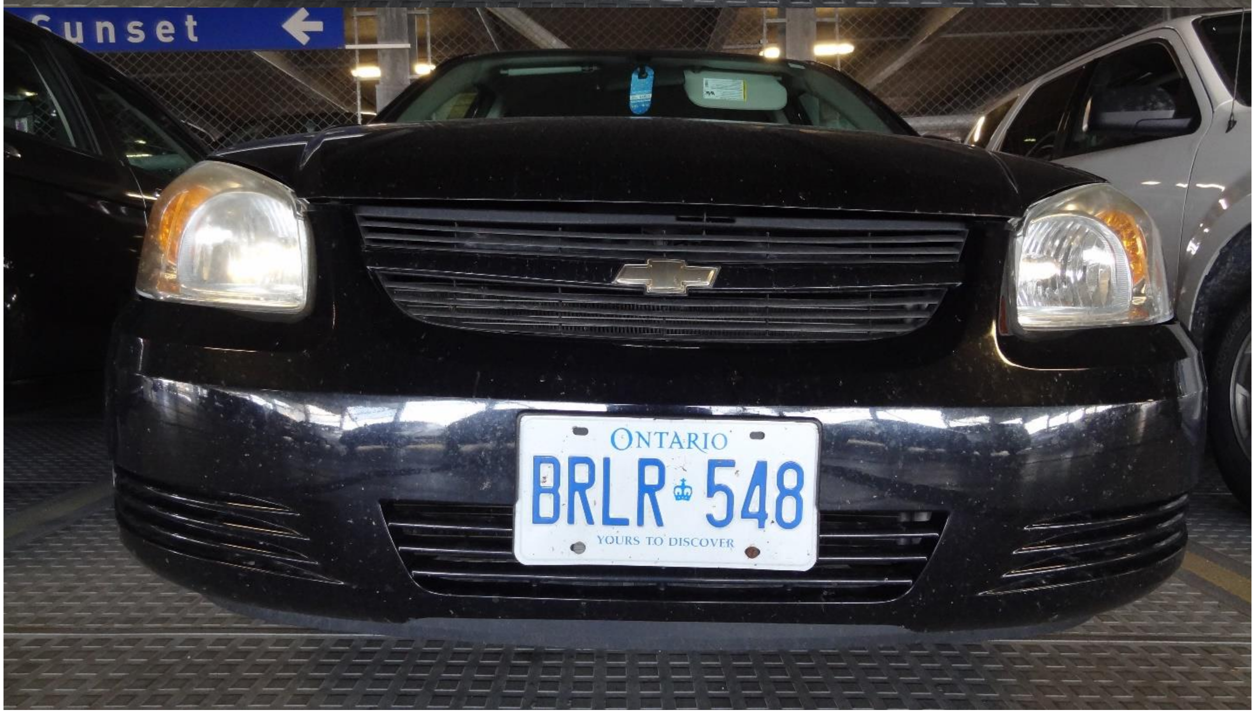
<table>
<tr><td>Input Image</td><td>
</td><td>
</td></tr>
<tr><td>Eroded
Image</td><td>
</td><td>
</td></tr>
<tr><td>Gray Scale
Image</td><td>
</td><td>
</td></tr>
<tr><td>Image
Subtraction
n</td><td>
</td><td>
</td></tr>
</table>

Image Subtraction n1		
Image Subtraction Final		

Appendix 3: Sample Dataset Images

3.1 ALPDR System

A few of the dataset Images are below:




GMC
ONTARIO
BVJL 383
YOURS TO DISCOVER


Ford
ONTARIO
BTHX 314
YOURS TO DISCOVER


ONTARIO
APR 16
BYDT 423
YOURS TO DISCOVER
ONTARIO
AC 85013
YOURS TO DISCOVER
ONTARIO
BMJX 617
YOURS TO DISCOVER


CHRYSLER
Jeep
DODGE
ONTARIO
BXYY 291
WINDSOR CHRYSLER
DODGE


COBALT LT
ONTARIO
BDPF 005
YOURS TO DISCOVER


ONTARIO
AWLF 209
YOURS TO DISCOVER


ONTARIO
BTWV 396
YOURS TO DISCOVER


ONTARIO
BVMC 099
YOURS TO DISCOVER


Level 3 -
ONTARIO
BTTN 543
YOURS TO DISCOVER


ONTARIO
MACKIE30
YOURS TO DISCOVER
LAND ROVER

3.2 VSDR System

The following are a few images for Vehicle Shape detection and recognition.

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